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Cyber-Physical Visual Management Systems in the Digital Lean Manufacturing World

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Abstract. The importance of Visual Management (or “Mieruka” as it is called in Japanese) has been largely demonstrated over the last few years, especially when it comes to the creation and management of data-rich environments for effective and efficient data-driven decision-making, such as digital lean smart factories. Although the different functions of visual systems are already known by the scientific community, further analysis of the capabilities and benefits provided by these tools, especially when enhanced with modern digital technologies, has yet to be provided. Therefore, this paper aims to frame a list of capabilities of the current physical visual systems, and their cyber/digital equivalents, according to a reference framework called the “7Is”, which was extracted from a review of the current literature available. This may serve as a valid common reference for future research on this topic.

Keywords: Digital Manufacturing, Smart Manufacturing, Lean Manufacturing, Digital Lean Manufacturing, Visual Management, Mieruka, Digitalization.

1 Introduction

Digital technologies have given rise to a new era of lean manufacturing, which extends the *lean philosophy* to the cyber world, known as “Digital Lean Manufacturing (DLM)”. This new DLM world is characterised by “new data acquisition, data integration, data processing and data visualization capabilities to create different descriptive, predictive and prescriptive analytics applications to detect, fix, predict and prevent unstable process parameters and/or avoid quality issues inside defined tolerance ranges that may lead to any type of waste within the cyber- and physical- worlds” [1].

In this paper, from a *Visual Management perspective*, particular attention is given to the new *data visualization capabilities* offered by novel *digital technologies*, which play a significant role in spreading the right information; in the right visualization type, medium, and frequency; to the right person(s); at the right time for decision-making and/or action-taking. Furthermore, this paper aims to create awareness of the potential *information overload phenomena* [2] in smart factories that are data-rich environments with the “danger” of exceeding the information processing capacity of their workers, which may lead to counteract the benefits of data availability for data-driven decision-making. Hence, proper *information visualization* is key to minimising the workers’

cognitive load (and avoiding *Cognitive Muri/Overburden*) in data-rich environments for effective and efficient data-driven decision-making and action-taking.

The ultimate goal of this paper is to deepen the knowledge regarding the implications of adopting new *digital technologies* to support traditional *visual management practices and systems' functions*. Based on a literature review, the functions that characterize present *Visual Management Systems* are first identified and then used by a team of lean and digital lean experts to create a map of the opportunities and limitations arising from their digitization: *Digital Visual Management Systems*.

2 Visual Management

Visual Management (VM) (or *Mieruka* as it is called in Japanese) is “the lean practice of connecting and aligning organisational information with the process environment and stakeholders, employing stimuli that directly address one or more human senses to call for action” [3]. VM is encouraged in lean management because workers respond to and process *visual information* much better than with any other of their senses [4]. In fact, 90% of information transmitted to the brain is “visual”, and workers tend to remember only 20% of what they hear, yet 80% of what they saw [4]. Moreover, VM is also promoted, particularly for shopfloor/factory management, because it helps to understand the state of production, whether it is running correctly or not, as well as the configuration of different working areas and stations, and how to reach them and what to pay attention to – e.g. for troubleshooting [5].

VM has been mainly developed, over the years, through practitioner efforts rather than theoretical insights; therefore, there is actually a lack of a solid, shared theoretical background about its development and practice [6]. In particular, it is unclear which *Mieruka functions* [3] lead to which specific benefits, and which are the challenges associated with their application [6]. This “uncertainty” becomes even more relevant today because of the *digitization* and/or *digital-enhancement efforts* of many of the *Mieruka functions* as lean researchers and practitioners rethink traditional VM systems and tools for the new DLM world (or Industry 4.0) [7]. Furthermore, the *digitization of information* and *digital transformation of processes* can lead to new forms of waste and overload [1,8]. Therefore, it becomes of significant importance to understand whether and to what extent *digitization* changes the different functions of *Mieruka*, improving or worsening their relative effects.

3 Methodology

This research work was developed in two steps. First, a literature review on *Mieruka*, contextualized within the Lean Manufacturing paradigm, was carried out to understand the distinctive characteristics and functionalities of VM practices, systems, and tools. Web of Science, Scopus, and Google Scholar databases were consulted to collect useful papers related to the topic under analysis. The analysis was conducted independently by the authors of this paper with a theoretical and practical experience in (digital) lean manufacturing to identify the distinctive characteristics and functionalities of *Mieruka*.

An initial research attempt, carried out by inputting combinations of different keywords belonging respectively to the semantic fields of *Lean Manufacturing* (i.e. *Mieruka*) and *Visual Management* (with respective synonyms) allowed, by setting up

appropriate filters related to the scientific areas of competence (mostly related to the engineering field) and the required type of document (journal or conference papers or book chapters), to obtain an initial selection of 99 papers which, following the reading phase of the abstracts, was then narrowed down to a total of 75 analysed documents.

Some subsequent meetings have allowed resolving any differences of opinion, thus arriving at the construction of a shared map of VM characteristics and functions. Afterwards, and as the second step, a brainstorming session with factory managers and lean experts took place to understand how current *digitization* and *digital transformation efforts* are “affecting” traditional VM practices, systems, and tools on the shop floor, resulting in a final table (see Table 2) reporting the main benefits and the drawbacks regarding each of the *digitized* and/or *digitally-enhanced* features and functionalities identified in the literature review on *Visual Management Systems (VMSs)*.

4 Literature Review

The key importance of VM in working environments has been evidenced by the fact that this practice has always been a cornerstone of the Lean Manufacturing philosophy, and it is probably the most famous and adopted lean practice and tool in the world for its effectiveness. Indeed, *visual communication* is crucial to achieving better operational performance [9] and continuous improvement [10], as it facilitates instant monitoring of production activities while supporting staff involvement, by making information accessible to everyone for decision-making and action-tacking.

Scientific and managerial research suggests that *Mieruka practices* serve different operations management functions, but there are no studies in the literature that can provide a complete and comprehensive overview. The literature review conducted identified seven different functions absolved by *Visual Management*, which were called the “7Is”, each of these may actually bring benefits to one or more principles underlying the Lean Manufacturing paradigm as stated in the “4P Model”: Philosophy, Process, People & Partners, and Problem Solving [11]. A brief description of each of the seven “I” is reported in Table 1 with their main relationship with the 4Ps of Lean.

Table 1. Correlation between Mieruka’s Functions (7Is) and Liker’s [11] 4P Dimensions

| Mieruka’s Functions (7Is) | Involved P of Liker’s model |
|----------------------------------|--|
| Identify | Process (waste) |
| Inform | People about Process |
| Instruct/Illustrate | People on how to develop a Problem Solving |
| Involve | People (in the Process of optimization) |
| Instil/Inspire | Philosophy of lean |
| | Problem Solving approach |
| Improve | Process (transparency and performance) |
| Indicate | (how to) Plan a Process optimization |

4.1 The 7Is in Traditional Mieruka Systems

Identify – *Visual systems* have the function of helping people identify an object (be it a product, a piece of equipment, or a document) in the shortest possible time, resulting

in increased production efficiency. For instance, during *5S programs*, the adoption of “red tags” to identify unnecessary or unneeded items in workplaces can speed up the sorting process. Again, the use of tapes, symbols, and coloured shapes, facilitates the identification of spaces in which to store documents, materials, and equipment according to the principle of “*a place for everything and everything in its place*”, while the use of floor and wall signs allows the identification of special areas or areas where access is limited to personnel and authorized vehicles. In the case of *Kanban*, instead, the tag is used to identify the contents of a specific container clearly and unambiguously, as well as the areas where the material is to be used, to avoid any risks of error during the delivery phase. Finally, *visual system tools* also serve to rapidly identify problems that may arise in the manufacturing field, for instance, the *Value Stream Map (VSM)* is an effective map for providing a precise and immediate image of the production process, allowing operators and managers to grasp faster and more clearly the problems inherent in the operational processes, to quickly draw up effective interventions [3].

Inform – Getting all the most important information directly to a single location, such as a machine status update or the latest production news, is a distinctive feature of visual systems [12], particularly those referred to as *Visualization Boards*. The creation of an information point of reference for people within the company simplifies the flow of information, as it makes it possible to become aware of the organisational context simply and at a single glance. Through *Andons*, for example, light signals and messages on visualization boards allow personnel to be informed almost instantaneously about various critical issues that have arisen, from a machine downtime, unsatisfactory production yields, and quality problems, to missing items in the production line or the warehouse. On the other hand, the QCDSM dashboards placed close to a workstation or production line can allow the area or department manager to promptly check whether the daily safety, quality, efficiency, and productivity objectives have been reached, to establish the most appropriate corrective actions. The use of these dashboards has proven to be fundamental in providing continuous feedback regarding the state of a production system, as this practice provides an observer with a snapshot of the performance trend and relative deviations from company targets, again at a glance. *Visual tools*, though, not only simplify ‘top-down’ and ‘bottom-up’ communication between management and departments but also facilitate the sharing of information between departments and functions operating at the same hierarchical level. For example, through a standard graphical language, the VSM eases the exchange of opinions and ideas among optimization team members.

Instruct/Illustrate – *Visual signals* are often designated to ensure manufacturing consistency through operator training. Operators can be instructed using visuals and simple diagrams on standards and procedures related to work cycles and quality control, equipment maintenance, safety management, and material picking and unloading. This category typically includes *One Point Lessons (OPLs)*, simple written instructions aided by visual details (such as images, diagrams, and photos) designed to formalize an element of guidance and training on which steps, tools, and documents need to be used to efficiently carry out an operation, whether it be executive, control, or improvement. Making this kind of information available at the “point-of-use” for operators is key to reducing the amount of non-value-added activities [13]. Also, the *Kanban board* is a practical tool for instructing the operator, indicating with its three-coloured (i.e. red, yellow, and green) layout the logic of priorities that (s)he must adopt in production.

Involve – The adoption of *visual tools* such as *Visualization Boards* fosters a sense of shared ownership and connection to a team through a clear and public representation of team performance. For example, presenting operational results from individual teams on the corporate dashboard, rather than reporting the best team or operator on the boards in common areas of the factory, fosters positive internal competition and stimulates operators to challenge themselves for recognition from the company and their colleagues [12]. This climate of “positive” competition, which publicly rewards worthy teams without putting other crews in the shadow, improves *morale* among personnel through the encouragement of openness and willingness to share ideas and information by streamlining the flow of information and delivering it at the “point of use”. For example, the QCDSM boards that allow operators to intervene directly in the feedback process through reporting their productivity, safety, quality, and cost issues, stimulate the workforce to proactively participate in the decision-making processes, fostering commitment, and self-esteem. If implemented correctly, *VM* can provide a solid foundation for continuous improvement, which requires a systematic, incremental, and iterative approach throughout the company that involves employees at all levels.

Instil/Inspire – *Visual tools* create a positive tension within the workgroup that drives people to pursue discipline [14], especially in terms of “*building a habit of maintaining correct procedures*”. In this regard, both the adoption of OPL systems and operating instructions for the execution of production, control, maintenance, or material management processes help to define an operational and behavioural discipline to be followed, which compliance favours the reduction of uncertainty, reduces process variability, and improves the monitoring and control of activities. Another key aspect characteristic of any *Visual Management project* resides in its ability to increase information transparency. In this case, the implementation of *visual planning tools* such as *Kanban boards* and *A3 sheets*, characterized by a focus on the visibility of information inherent in production planning, quality management, and problem-solving processes, contributes to the creation of a clear information network that, in turn, sensitizes staff to seek greater awareness and control of organisational and decision-making processes. This leads to the empowerment of workers operating inside an organisation, as *visual tools* create the conditions for capturing more quickly and more effectively the inherent tacit knowledge, thus, speeding up the training process of workers as well as the development of a creative approach and orientation towards continuous improvement and problem-solving.

Improve – The adoption of *visual procedures* often allows to cut down non-quality and time-wasting connected to production and control activities, thus, generating a significant increase in the speed of execution [5]. The use of *Kanban*, for instance, helps to reduce production stops due to lack of material or delivery errors, if adequately supported by suppliers able to work according to the same kind of logic. *Visual Management* also encourages management by facts, namely the management of people and processes based on data and statistics rather than guesswork and intuition, which helps managers and team leaders guide and improve the quality of tasks and projects through the use of a rigorous methodology. *VSM*, for example, proves to be particularly adherent to this benefit, as it shows new opportunities for improvement at a glance through the creation of the future state value stream map.

Indicate (how to plan) – Thanks to their high versatility, *visual tools* facilitate planning processes of production activities and more. While the *Heijunka board* helps

to visually scan the pace of production in accordance with customer needs, the *Kanban board* supports the planning of improvement projects by displaying the contents of the work (by theme, assignment, deadline) and the optimization of the interventions, by separating actions in relation to the capabilities and availability of individuals in a specific period of time [14]. In line with the scientific method of problem-solving, the *PDCA cycle* supports the team for optimisation in defining objectives, constructing a plan of action, and its execution and control. The adoption of *visual tools*, finally, enables the corrective actions necessary for the realignment between objectives and performances achieved. In this sense, the *X-Matrix* is a powerful method for effective strategy deployment and communication of long-term goals.

4.2 The 7Is in Digital or Digitally-enhanced Mieruka Systems

Identify – This *Mieruka function* has been digitally-enhanced in the DLM world with the use of *Auto-ID (Automatic Identification) technologies* such as RFID (Radio-Frequency Identification) and NFC (Near Field Communication) that offer numerous benefits over traditional paper-based tagging and labelling solutions in the Industrial Internet of Things (IIoT). For example, offering proactively or passively not only the description of a *smart object* but also information about its location, availability, condition, usage, etc. [15]. Moreover, *Computer Vision Systems* are becoming big allies for automatic product quality inspection [16]. When it comes to the identification of spaces, *LED tapes, e-labels, and projection mapping technologies* can offer digitally-enhanced solutions to provide clear indications for fast picking and storage tasks to workers based on pick-to-light & put-to-light solutions aimed at reducing or eliminating the human error in these finding & storage operations in warehouses and supermarkets in the production line [17] (i.e. a kind of *Digital Poka-Yoke*). In the case of *e-Kanban, smart bins* enhance visual feedback (with e-labels), eliminate manual counting (with the help of sensors), and enable automatic e-notifications for restocking tasks, assisting workers in efficiently managing their inventory levels [18]. Finally, *IIoT-enabled Value Stream Maps (VMSs)* can offer, thanks to smart sensors, accurate and always actual (a.k.a. real-time) information about machine and human workstations performance to avoid material still standings due to lack of instructions [19].

Inform – *Visualization* [20] and *Digitalization* [21] are of the utmost relevance when improving information sharing and visualization methods in the DLM world. The creation of *IIoT-based Visualization Boards* offers great benefits like the automatic gathering of shopfloor data and its updated display in digital dashboards for supporting data-driven decision-making processes [22]. Moreover, the *digital-interactive interfaces* of modern digital dashboards offer the opportunity to display information (i.e. data visualization) according to their user requirements providing the right amount of information, in the right format depending on the complexity of the decision to be made, so information overload and misinterpretation be avoided [22]. Furthermore, through *Digital Andon devices* (i.e. tablets, smartphones, smartwatches, and head-mounted displays), information can be proactively delivered and visualized by the right workers using targeted e-notification systems to quickly react to any production abnormalities [23]. Lastly, the use of *QCDSM Digital and IIoT-based Dashboards* allows instant (i.e. display of “real-time” information) and proactive (i.e. alerting based on predictive analytics) feedback regarding the present and possible future state of a production system [22,23].

Instruct/Illustrate – *Visual signals* are designated to ensure production consistency through operator training. In the DLM world, such signals have become also “digital” by means of *Augmented Reality (AR) devices*, such as smart glasses and projectors, that overlaid in real-time information to the worker. Hence, AR can be considered a key enabling technology for improving the transfer of information from the digital to the physical world in a non-intrusive way for the operator, becoming an enabler of *Digital Assistance Systems* for reducing human errors (i.e. a *Digital Poka-Yoke*) and at the same time reducing the dependence on printed work instructions, computer screens, and operator memory for augmented operator performance [24].

Involve – *Digital and IIoT-based Leaderboards*, as “gamified” visual performance boards [25], can provide real-time performance information and foster positive internal competition and stimulate operators to challenge themselves for recognition from the company and their colleagues at the same time that the workforce is driven to the desired QCDSM production objectives. Furthermore, also the DLM world, the use of *Visualization Boards* with *Digital-Interactive Interfaces* (i.e. with dimmed visual elements, drop-down menus, slicers, etc.) promotes workforce engagement with the visual information displayed on the boards by offering workers the possibility of customizing their dashboards, faceting the data in these through data filters and slicers, and cross-highlighting and annotating the data available for a more personal analysis of the data items that are relevant for him/her [26] – e.g. for performance monitoring and continuous improvement action.

Instil/Inspire – In the DLM world, *Digital Poka-Yokes* can provide digitally-enhanced visual aids and light/voice-guided steering mechanisms to prevent deviations from Standard Work or Operating Procedures (SWOs/SOPs) so defects can avoid, and the speed of work be increased in a reliable way [27]. Furthermore, *Digitally-enhanced Visual Planning Tools* such as *Kanban boards* and *A3 sheets* offer new planning and control as well as problem-solving features based on integrated simulation technologies for testing and scheduling of countermeasures before their life implementation, and later progress tracking based on IIoT technologies [28].

Improve – The adoption of *AR-enhanced Visual Procedures* in the DLM world often allows for higher productivity rates and error-proof processes with the help of *Digital Poka-Yokes*. *Digital Assistance Systems* can act as guiding and fail-safe mechanisms, as well as teaching-learning mechanisms, facilitating making the correct action far easier than the mistake and detecting any mistake for immediate correction [24,27]. Furthermore, the use of *e-Kanban* helps to identify the exact amount of what and when is needed [18]. Lastly, *Visual Management* promotes a data-driven approach for decision-making using descriptive, predictive, and prescriptive data analytics to detect, fix, predict and prevent unstable process parameters and avoid quality issues (e.g. VSM 4.0 [19], Quality 4.0 [29]).

Indicate (how to plan) – In the DLM world, *IIoT-based Heijunka boards* are able to automatically scan the pace of production, thanks to smart sensors, and support a “truly holistic” production (re-)scheduling in real-time and just-in-sequence logic for avoiding waste risk creation due to the lack of a systemic scheduling approach [1,30]. Furthermore, a *Digitally-enhanced PDCA cycle* can automate and/or augment its data acquisition, data integration, data processing, and data visualization activities with the use of IIoT, data analytics, and real-time visualization technologies for avoiding continuous improvement decisions/actions based on obsolete data [31].

5 Discussion

A growing interest in benefits and criticalities concerning the application of *Digital Technologies* in the field of *Visual Management* has risen in recent years [32], but whether and to what extent the adoption of these technologies is effectively useful or not is still unclear. Based on the interpretation of the “7Is” functions, a discussion with some lean and digital lean manufacturing experts has enabled the building of Table 2, where the pros and the cons of emerging *digital technologies* supporting *Mieruka* are summarized.

Table 2. Benefits and Criticalities of the Influence of Digital Technologies on Mieruka

| | Pros | Cons |
|---------------------------------|---|--|
| Identify | <ul style="list-style-type: none"> • Computer vision systems can be used to identify product quality deviations and communicate these to the operators. • pick-to-light and put-to-light devices serve as digital poke-yokes. | <ul style="list-style-type: none"> • Over-reliance on technology may cause operators to feel redundant, causing boring work. |
| Inform | <ul style="list-style-type: none"> • Augmented Reality (AR) and Intelligent Personal Assistants (e.g. chatbots) can enhance the transmission of relevant information to human operators. • Smart devices (e.g. phones/tablets) can serve as digital andons. | <ul style="list-style-type: none"> • AR headsets still cause motion sickness in many users; projection mapping solutions and digital widescreens may be a safe middle-ground. |
| Instruct/ Illustrate | <ul style="list-style-type: none"> • AR can be used to instruct operators on standard work procedures, both in training and in the operation phase. AR can also be used to illustrate important knowledge points (quality critical data). | <ul style="list-style-type: none"> • AR headsets still cause motion sickness in many users, consequently, traditional means of communicating knowledge points may remain the preferred choice of workers. |
| Involve | <ul style="list-style-type: none"> • Mobile computing and wearables can be used to proactively involve operators in problem-solving (e.g. quality control circles). | <ul style="list-style-type: none"> • General Data Protection Regulation (GDPR) and observation of operators' habits may cause issues with their involvement (the connectivity paradox). |
| Instil/ Inspire | <ul style="list-style-type: none"> • Karakuri IIoT (low-cost IIoT) can be used to inspire operators to discover new means of triggering and communicating visual information. • Digitalization of the A3 process on smart devices. | <ul style="list-style-type: none"> • IIoT-push could lead to the creation of digital waste rather than contributing to solving genuine problems. • A3 reports writing with a pen and paper requires more mental energy and engages more areas of the brain than when pressing keys on a computer keyboard or smart device. |

| | | |
|-----------------|---|---|
| Improve | <ul style="list-style-type: none"> The visual communication of real-time data using big data analytics and cloud/edge computing can serve as a driver for improvement activity (e.g. descriptive, predictive, and prescriptive analytics). | <ul style="list-style-type: none"> Operators may become dependent on the data to identify “improvement” rather than using their own eyes and hands to find facts at the Gemba. |
| Indicate | <ul style="list-style-type: none"> Electronic transmission of visual production instructions and signals/ cues (e.g. e-Kanban) | <ul style="list-style-type: none"> e-Kanban may be falsely optimized, disengaging human creativity to further improve the process. |

6 Conclusions and Further Research

A general overview of various *Visual Management* (or *Mieruka*) lean practices were presented in this paper, which looks at its seven main functions (here referred to as the “7Is”) that have been supported by classic *physical* visual practices, systems, and tools out from the traditional Lean Manufacturing world, and now are aimed to be supported as well by new *cyber/digitally-enabled ones* emerging from the novel *Digital Lean Manufacturing world* [1]. Furthermore, a first effort to understand the pros and cons of this *digitalization phenomenon of Visual Management* was conducted. Nevertheless, this should be considered as further research work as lean researchers and practitioners continue to rethink traditional VM practices, systems, and tools in light of new their potential digital capabilities, which are yet to be studied in detail to clearly determine their specific benefits and implementation challenges so these contribute to digitally-enhanced value-creation and not digital waste (e.g. information overload).

References

- Romero, D., Gaiardelli, P., Powell, D., Wuest, T., Thürer, M.: Digital Lean Cyber-Physical Production Systems: The Emergence of Digital Lean Manufacturing and the Significance of Digital Waste. IFIP, AICT, 535:11-20 (2018)
- Edmunds, A., Morris, A.: The Problem of Information Overload in Business Organisations: A Review of the Literature. Information Management, 20:17-28 (2000)
- Tezel, B.A., Koskela, L.J., Tzortzopoulos, P.: The Functions of Visual Management. International Research Symposium, pp. 201-219 (2009) – <http://usir.salford.ac.uk/10883/>
- Sivak, M.: The Information that Drivers Use: Is It Indeed 90% Visual?. Perception, 25(9):1081-1089 (1996)
- Galsworth, G.D.: Visual Workplace/Visual Thinking. Visual-Lean Enterprise Press (2005)
- Koskela, L., Tezel, A., Tzortzopoulos, P.: Why Visual Management? 26th Annual Conf. of the International Group for Lean Construction. Chennai, India, pp. 250-260 (2018)
- Fenza, G., Loia, V., Nota, G.: Patterns for Visual Management in Industry 4.0. Sensors, 21(19):6440 (2021)
- Romero, D., Gaiardelli, P., Powell, D., Thürer, M., Wuest, T.: Cyber-Physical Waste Reduction and Elimination Strategies in the Digital Lean Manufacturing World. IFIP, AICT, 566:37-45 (2019)
- Bititci, U., et al.: Impact of Visual Performance Management Systems on the Performance Management Practices of Organisations. Production Research, 54(6):1571-1593 (2015)

10. Olszewski, L., Bhattacharya, A., Harrington, T.S.: Exploring Visual Management and Continuous Improvement in a Manufacturing Context: A Structured Bibliometric Analysis. 23rd Cambridge Int'l. Manufacturing Symposium – doi: 10.17863/CAM.45890 (2019)
11. Liker, J.K. (2004) *The Toyota Way*, 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill, New York.
12. Eaidgah, Y., et al.: Visual Management, Performance Management and Continuous Improvement: A Lean Manufacturing Approach. *Lean Six Sigma*, 7(2):187-210 (2016)
13. Badger, A.S., et al.: A Methodology to Enhance Equipment Performance using the OEE Measure. *European Journal of Industrial Engineering*, 2(3):356-376 (2008)
14. Tezel, A., et al.: Visual Management in Production Management: A Literature Synthesis. *Journal of Manufacturing Technology Management*, 27(6):766-799 (2016)
15. Rahmadya, B., et al.: Ultra-High Frequency Band Radio Frequency Identification Tag Enabling Color-Change for Inventory Management Systems: A Color-Change Tag. *IEEE Journal of Radio Frequency Identification*, 4:101-106 (2020)
16. Vergara-Villegas, O.O., et al.: Automatic Product Quality Inspection Using Computer Vision Systems. *Lean Manufacturing in the Developing World*, pp. 135-156 (2014)
17. Hofmann, E., Rüsçh, M.: Industry 4.0 and the Current Status as well as Future Prospects on Logistics. *Computers in Industry*, 89:23-34 (2017)
18. El Abbadi, L., El Manti, S., Houti, M., Elrhanimi, S.: Kanban System for Industry 4.0. *Engineering and Technology*, 7(4.16):60-65 (2018)
19. Hartmann, L., Meudt, T., et al.: Value Stream Method 4.0: Holistic Method to Analyse and Design Value Streams in the Digital Age. *Procedia CIRP*, 78:249-254 (2018)
20. Lindlöf, L., Södererg, B.: Pros and Cons of Lean Visual Planning: Experiences from Four Product Development Organisations. *Technology Intelligence and Planning*, 7(3):269-279 (2011)
21. Fast-Berglund, Å, Harlin, U., Åkerman, M.: Digitalisation of Meetings – From White-board to Smart-boards. *Procedia CIRP*, 41:1125-1130 (2016)
22. Steenkamp, L.P., Hagedorn-Hansen, D., Oosthuizen, G.A.: Visual Management System to Manage Manufacturing Resources, *Procedia Manufacturing*, 8:455-462 (2017)
23. Mohamad, E., et al.: Framework of Andon Support System in Lean Cyber-Physical System Production Environment. *Manufacturing Systems Division Conference*, pp. 404-405 (2019)
24. Rodriguez, L., Quint, F., Gorecky, D., Romero, D., Siller, R.: Developing a Mixed Reality Assistance System based on Projection Mapping Technology for Manual Operations at Assembly Workstations, *Procedia Computer Science*, 75:327-333 (2015)
25. Keepers, M., Romero, D., Hauge, J.B., Wuest, T. Gamification of Operational Tasks in Manufacturing. *IFIP, AICT*, 591:107-114 (2020)
26. Sarikaya, A., Correll, M., et al.: What Do WeTalk About When We Talk About Dashboards? *IEEE Transactions on Visualization and Computer Graphics*, 25(1):682-692 (2019)
27. Sposito-Valamede, L., Santos-Akkari, A.C.: Lean 4.0: A New Holistic Approach for the Integration of Lean Manufacturing Tools and Digital Technologies. *Int'l. Journal of Mathematical, Engineering and Management Sciences*, 5(5):851-868 (2020)
28. Nakazawa, S., Tanaka, T.: Development and Application of Kanban Tool Visualizing the Work in Progress. *5th Int'l. Congress on Advanced Applied Informatics*, pp. 908-913 (2016)
29. Romero, D., Gaiardelli, P., Powell, D., Wuest, T., Thüerer, M.: Total Quality Management and Quality Circles in the Digital Lean Manufacturing World. *IFIP, AICT*, 566:3-11 (2019)
30. Kjellsen, H.S., et al.: Heijunka 4.0 – Key Enabling Technologies for Production Levelling in the Process Industry. *IFIP, AICT*, 630:704-711 (2021)
31. Peças, P., Encarnação, J., et al.: PDCA 4.0: A New Conceptual Approach for Continuous Improvement in the Industry 4.0 Paradigm. *Applied Sciences*, 11(16):7671 (2021)
32. Tezel, A., Aziz, Z.: From Conventional to IT-based Visual Management: A Conceptual Discussion. *Information Technology in Construction*, 22:220-246 (2017)